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AN/BRN-7 COMPUTER PROGRAM SPECIFICATION. VOLUME VII. PROPAGATIO--ETC(U)

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- ☒ This submittal applies to both AN/BRN-7 and AN/SRN-( ).

CONTRACT NO: N00039-73-C-0209

PROGRAM NAME: AN/BRN-7

CDRL No: A01D, A01E, A01F

Title of CDRL: Computer Program Design Specification  
Computer Subprogram Design Document  
Data Base Design Document

Title of Doc: AN/BRN-7 Computer Program Specification  
NORT 73-48  
Volume 2 thru 13

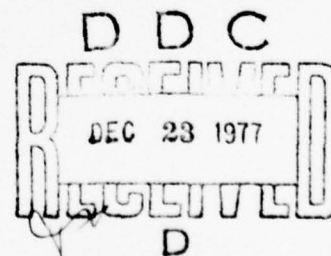
Date: 1/16/74

Initial Submittal: <input checked="" type="checkbox"/>	Release: <u>AP 5</u> <u>1-16-74</u>
Resubmittal: <input type="checkbox"/>	Authentication:

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A4734 X574  
Orgn. No. and Ext.

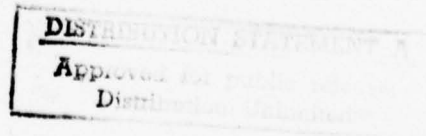
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VOL VII

**NORTHROP**

Electronics Division

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NORT 73-48

AN/BRN-7 COMPUTER  
PROGRAM SPECIFICATION

Volume VII  
PROPAGATION PREDICTION SUBPROGRAM DESIGN

October 12, 1973

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Volume VII  
of the  
AN/BRN-7 OMEGA COMPUTER  
PROGRAM SPECIFICATION

Volume

- I Performance Specification
- II Design Specification
- III Synchronization Subprogram Design
- IV OMEGA Processing Subprogram Design
- V Tracking Filter Subprogram Design
- VI Kalman Filter Subprogram Design
- VII Propagation Prediction Subprogram Design
- VIII Navigation Subprogram Design
- IX Executive Subprogram Design
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## SECTION 1

## SCOPE

## 1.1 IDENTIFICATION

Volume I, Submarine OMEGA Computer Program Performance Specification, defines the functional requirements for the Submarine OMEGA Computer Program which is used by the AN/ARN-99 OMEGA Navigation Set. The Navigation set and the OMEGA program together comprise the Submarine OMEGA Navigation System. The tape which defines the computer program is entitled AN/BRN-7 Navigation Program.

Volume II, Submarine OMEGA Computer Program Design Specification, allocates the functional requirements of Volume I to the computer routine and sub-program level.

This volume describes the subprogram designated as Propagation Prediction, which has the abbreviation PP in the program listing (Volume XIII).

## 1.2 PROPAGATION PREDICTION SUBPROGRAM TASKS

1.2.1 Overview

In order to successfully determine the current submarine position from the phase information received, it is necessary to know the phase velocity of the incoming wave along the path, and the path length. To obtain a more accurate estimate of submarine position, we will investigate a number of effects (magnetic, day/night (diurnal), ground conductivity, and variations in radius of the earth) that cause position to deviate from that calculated using constant velocity over an assumed perfect sphere.

Operation of the OMEGA Navigation System is based on the measurement of the phase of several transmitters operating in the 10-14 kHz electromagnetic spectrum. It has been established that the eight proposed OMEGA transmitters will cover the earth with signal levels adequate to permit that phase measurement. Furthermore, it is generally accepted that signals in this spectrum propagate through a waveguide made up of two concentric spheres, one sphere is the earth; the other is the ionosphere.

Under ideal conditions a simple phase measurement would suffice to precisely locate a receiving station. However, the walls of the waveguide are not perfect and are affected by several parameters, specifically the effect of the sun on the ionosphere; earth's magnetic field; ground conductivity, and others. These imperfections in the waveguide walls cause changes in the propagation of the electromagnetic signal, the phase velocity, which reduce the accuracy of the phase measurement.

The phase velocity of such waves in a perfect waveguide with this geometry has been found to depend on the width of the waveguide (the height of the ionosphere) and on the electrical conductivity of the surfaces. The electric conductivity of the earth's surface is important, as well as that of ionosphere. In the case of the ionosphere, the problem is complicated theoretically because a continuous wall does not exist; rather, the electron density and collision frequency vary with height in some manner which can be approximated as exponential. The effect of the earth's magnetic field on the phase velocity must also be considered. This has been analyzed theoretically and the asymmetry between propagation from east to west and from west to east has been observed.

These factors, along with one to account for the oblateness of the earth, are incorporated into a computer program designed to provide incremental real-time corrections along the propagation path.

#### 1.2.2 Tasks

There are four tasks of the Propagation Prediction Subprogram. They are reflected in Figure 1.

- a) Initialization: Calculation of those environmental parameters which are independent of frequency and need only be calculated once. Included are:
  - The central path angle between station and OMEGA receiver,
  - The first magnetic parameter,
  - The seasonal Index, and
  - The sun vector.
- b) Integration Over the Transmission Path: In order to evaluate the effect of the ionosphere on the transmitted signal, it is necessary to superpose the known signal path on the model of the world contained in the subprogram. The following subtasks are frequency or path dependent:
  - Calculation of the diurnal constants,
  - Auroral compensation,
  - Earth conductivity Index,
  - Diurnal function and average,
  - Correction factors for propagation modes, and
  - Integration.
- c) Generation of Output Data: As a result of the incremental integration the subprogram generates:
  - Averaging constant; correction for incremental integration,
  - Base station control angle; used for phase,

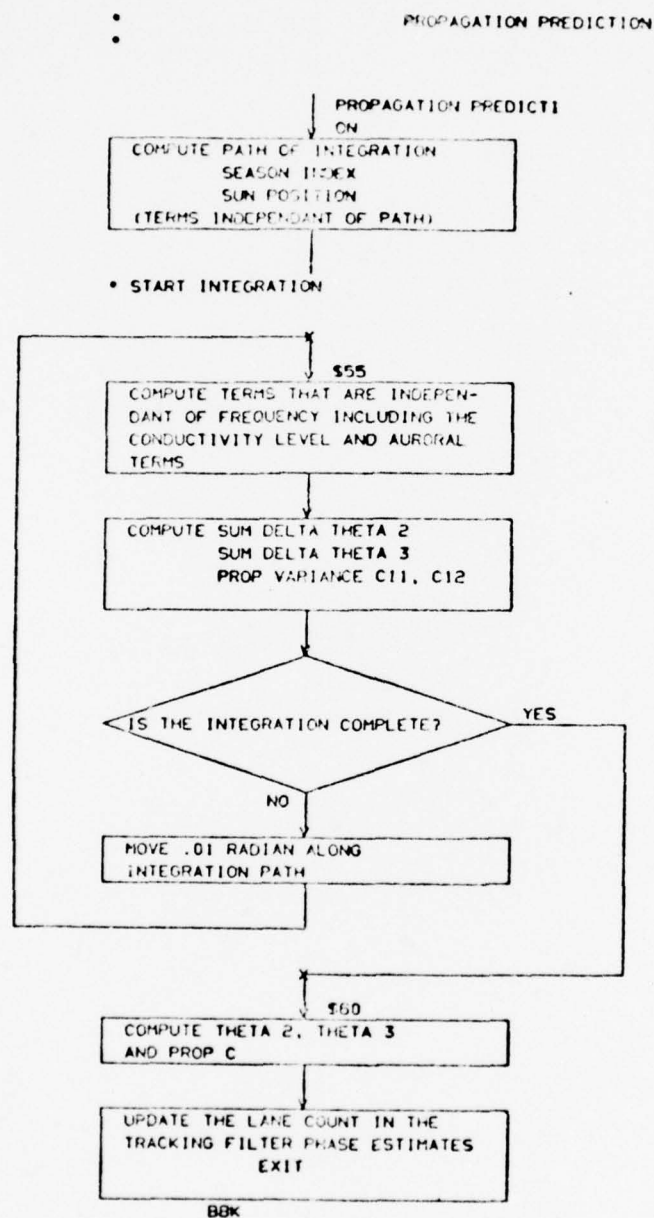


FIGURE 1



- Propagation Correction,  $\theta_3$ .
- Predicted Variance  $\sigma_{PPi}^2$
- Spherocdal Correction,  $\theta_2$ .

d) Tracking Filter Update: Includes:

- Predicted Tracking Filter measurement.
- Lane count corrections.

## SECTION 2

## APPLICABLE DOCUMENTS

- a) Submarine OMEGA Computer Program Performance Specification (Volume I of the Submarine OMEGA Computer Program Specification)

## Applicable Sections:

- 3.1 Introduction
- 3.2 Functional Description
  - 3.2.5 Detailed System Operations
- 3.3 Detailed Functional Requirements
  - 3.3.10 Tracking Filters
  - 3.3.11 Combinational Kalman Filter
  - 3.3.12 Propagation Prediction
- b) Submarine OMEGA Computer Program Design Specification (Volume II of the Submarine OMEGA Computer Program Specification).
- c) NORT 68-66, NAP70 User's Manual, July 1968.
- d) NORT 68-115A, Detailed Description of NDC-1070, Computer Instructions, Revision A, February 1970.
- e) NORT 69-87A, NDC-1070 Flow Chart Program, User's Manual.

## SECTION 3

### REQUIREMENTS

In order to understand the sub-program description contained in the following pages, it is necessary that the reader will have become familiar with the associated functional requirements found in Volume I, Performance Specification, and with the sub-program allocation found in Volume II, Design Specification.

#### 3.1 DETAILED DESCRIPTION

##### 3.1.1 Reference Labels to Flow Diagrams

The code used to reference the particular block in the flow diagrams, Section 3.2, is as follows: The first number is that page number found in the upper right corner of the diagrams. This will be followed by a slash sign (/) to separate the page number from the block designator. The designator will either be a mnemonic label (e.g., TEST SYNC), a local label indicated by a dollar sign (\$), or an integer. The two types of labels reference the particular information block, on the given page, to which the label is attached. The integer number, n, means that the referenced block is the nth block from the top of the page; p8/3 would refer to page 8 and the third information block down.

Finally, the label p1/\$ 2 + 3 refers to page 1, and the 3<sup>rd</sup> information block after the label \$ 2. p2/7, 8, 9 refers to page 2 and the 7<sup>th</sup>, 8<sup>th</sup>, and 9<sup>th</sup> blocks.

##### 3.1.2 Description of Flow Diagrams

###### 3.1.2.1 Initialization

- a) Central Path Angle; p1/PROPAGATION PREDICTION, 2, 3, 4:

After setup of the registers the subroutine THETA 1 is called to calculate the earth central angle between the submarine and the station selected by the argument.

$$\theta_1 = \text{ATAN} \left( \frac{|\vec{S} \times \vec{R}_1|}{\vec{S} \cdot \vec{R}_1} \right)$$



where  $\vec{R}_1$  = geocentric unit vector directed to the submarine estimated position  
 $\vec{S}$  = the geocentric unit vector directed to the station  
 and  $0 < \theta_1 < \pi$

b) First Magnetic Parameter;  $A_2$ , p1/5:

Obtain the unit vector,  $\vec{AX}$ , normal to the path of transmission from the station to the submarine receiver

$$\vec{AX} = \frac{\vec{S} \times \vec{R}_1}{|\vec{S} \times \vec{R}_1|}$$

p1/6:

$P_1, P_2, P_3$  are components of the integration position  $\vec{P}$ , oriented in the geocentric axis. This vector is initialized to the transmitter position coordinates, then moved along the propagation path in increments of  $d\theta$  radians as the integration progresses.

$$d\theta = 0.01 \text{ radian}$$

$$P_1 = S_1$$

$$P_2 = S_2$$

$$P_3 = S_3$$

p2/1:

$A_2$  is "The first magnetic parameter" and NP is a constant geocentric unit vector directed toward the magnetic north pole, and is given by:

$$\vec{NP} = (0.9664, 0.0044864, -0.25705)$$

$$\text{Calculate: } A_2 = -(\vec{AX} \cdot \vec{NP})$$

c) Seasonal Index IS; p2/2 through p3/6:

The seasonal index IS will be used in estimating the diurnal effect later. Theoretically the seasonal year can be segmented into 24 2.16-week periods. However, the currently used diurnal table requires only five entries.

TABLE 1 SEASONAL INDEX

IS	CALENDAR SPAN
0	JAN 1 - JAN 15
3	JAN 16 - JAN 31
6	FEB 1 - JUN 30
9	JUL 1 - DEC 15
12	DEC 15 - DEC 31

d) Sun Vector; S(I), p4/\$ 2:

Computation of the sun vector  $S(I) = S(1), S(2), S(3)$ . These form a geocentric unit vector representing solar information required to compute the diurnal function; i.e., a unit vector originating at the earth's center, pointing at the sun.

- 1) To start,  $D_m$ , the number of days since Jan 0.0, of 1968 is calculated, to be used in determining the sun position, and from that the daylight portion of the propagation path.

This can be accomplished by determining the number of days in prior years, looking up in Table 2 the number of days in the months preceding the current one, and adding these to the number of days already past in the current month, plus the fractional part of the current day.

TABLE 2 DAY OF THIS YEAR

Current Month	M (Jan = 1, Dec = 12)	Dm (Days in prior months, since Jan 1)
Jan 31	1	0
Feb 28	2	31
Mar 31	3	59
Apr 30	4	90
May 31	5	120
Jun 30	6	151
Jul 31	7	181
Aug 31	8	212
Sep 30	9	243
Oct 31	10	273
Nov 30	11	304
Dec 31	12	334

D = Number of days since Jan 0.0, 1968

$$D = 365 \begin{matrix} \uparrow \\ \text{(Last two digits)} \end{matrix} (\text{year} - 68) + \begin{matrix} \uparrow \\ \text{(From table above)} \end{matrix} D_m + (\text{Number of days in current month}) + \text{LEAP} \\ + \frac{(3600) (\text{hrs}) + (60) (\text{min}) + \text{secs}}{86400} \text{ (fraction of present day)}$$

where LEAP = number of Feb 29 days between Jan 1, 1968 and present.

2) E, the fractional part of D + 0.5

$$E = (D + 0.5), \text{ modulo } 1$$

3)  $L_s$ , the longitude of the sun

$$L_s = K_1 D + K_2$$

where  $K_1 = 0.0172027914$

$$K_2 = 4.8649521$$

$K_2$  represents  $L_s$  on Jan 1, 1968 and is subject to update to current year.

- 4)  $M_s$ , the orbital angle of the earth relative to the perihelion (point in earth's orbit at which earth is closest the sun).

$$M_s = K_3 D + K_4$$

where  $K_3 = 0.0172019699$

$$K_4 = 6.21950155$$

$K_4$  represents  $M_s$  on Jan 1, 1968 and is subject to update to current year.

- 5) First complement of sun vector

$$S(1) = K_5 \sin L_s$$

where  $K_5 = 0.39784368$  and is the tilt of sun's orbit.

- 6)  $L$ , sun's apparent longitude

$$L = -2\pi E - K_6 \sin M_s - K_7 \sin (2L_s)$$

where  $K_6$  and  $K_7$  are ellipticity corrections

$$K_6 = 0.0334440$$

$$K_7 = 0.04127339$$

- 7) Second complement of sun vector

$$S(2) = (1 - S(1)^2)^{\frac{1}{2}} \cos L$$

- 8) Third complement of sun vector

$$S(3) = (1 - S(1)^2)^{\frac{1}{2}} \sin L$$

## 3.1.2.2 Path Integration

p4/\$ 55 through p13/1 constitutes the main iteration algorithm where the Propagation Prediction terms will be obtained by integration in incremental steps of 0.01 radian.

- a) Diurnal Constant Vector, FM; p4/\$ 55 through p5/\$ 15:

Calculate the solar zenith angle,  $Z$ , from which the diurnal functions will be obtained by the table following.

$$\cos Z = \vec{P} \cdot \vec{S}(I)$$

Calculate the diurnal constant using the frequency, JF, and the season index IS.

TABLE 3 DIURNAL CONSTANTS

K (JF, IS)		JF = frequency index IS = season index		
IS	JF	10.2	11.3	13.6
0		0.271	0.241	0.212
3		0.300	0.268	0.237
6		0.340	0.304	0.269
9		0.210	0.186	0.162
12		0.241	0.214	0.187

NOTE: For IS = 6 and IS = 9, K is at present constant. It is possible that this would not be so in a more sophisticated version of the mode.

TABLE 4 DIURNAL FUNCTION

IF \ THEN	F (JF)	FM <sub>1</sub>	FM <sub>2</sub>	FM <sub>3</sub>
Cos Z < a	1	1	0	0
a ≤ Cos Z ≤ b	$\frac{\cos (Z-b) + K(JF, IS)(a-\cos Z)}{a-b}$	$\frac{\cos Z-b}{a-b}$	$\frac{a-\cos Z}{a-b}$	0
b < Cos Z	$\frac{K(JF, IS)(1-\cos Z)}{1-b}$	0	$\frac{1-\cos Z}{1-b}$	$\frac{\cos Z-b}{1-b}$

where a = -0.15

b = -0.04

k = (JF, IS) from Table 3.

and JF is the frequency index, 1, 2, and 3, corresponding to 10.2, 13.6 and 11-1/3.

IS is the season index determined in the description of p2/2.

$FM_1$ ,  $FM_2$ ,  $FM_3$  are three "scatter diurnal" functions that apply to all three frequencies.

F (JF) is the diurnal function, and is calculated for each frequency.

On the first pass through the diurnal calculations (above) for a given station, a value  $F(JF)_0$  is set equal to F(JF) for use in subsequent computations.

p5/\$ 20:

b) Auroral Compensation; p5/\$ 20 through p7/\$7 1+1"

The following algorithm will provide compensation for auroral effects when integrating over a path vector near the pole. For values of constants refer to Table 5.

The first calculation is the magnetic latitude AA6.

$$A5 = \{ \vec{P} \cdot \vec{NP} \} = \sin \phi$$

where  $\vec{NP}$  is a constant vector to north mag pole

$$AA6 = \{ \text{ASIN } (A5) \}$$

p5/\$ 20+1 through p6/7:

The auroral constants are determined by the following iteration.

$$\text{If } AA_6 < AU(1) \quad I = 1$$

$$AU(1) < AA_6 < AU(2) \quad I = 2$$

$$AU(2) < AA_6 < AU(3) \quad I = 3$$

$$AU(3) < AA_6 < AU(4) \quad I = 4$$

$$AU(4) < AA_6 \quad I = 1$$

$$AAUR = a(I) * AA_6 * AA_6 + b(I) * AA_6 + c(I)$$

$$BAUR = Da(I) * AA_6 * AA_6 + Db(I) * AA_6 + Dc(I)$$



TABLE 5 AURORAL CONSTANTS

		1	2	3	4
$\begin{matrix} \text{AU} \\ \text{A11} \\ \times \\ 10^{-6} \end{matrix}$	AU	1.02974	1.13446	1.16064	1.41371
	a	0	310.04	- 1805.55	60.30
	b	0	- 641.39	+ 4179.73	-171.32
	c	0	+ 331.71	- 2414.90	+121.65
	Da	0	+ 930.13	- 5197.77	- 93.80
	Db	0	-1905.09	+11840.17	+206.28
	Dc	0	+ 975.47	- 6731.36	-104.13

p7/§ 71:

Finish calculation of auroral constants.

$$B1 = -A2 / \sqrt{1 - (A5)^2} = \sin \theta$$

$$B2 = 1 - 2 (B1)^2 = \cos 2\theta$$

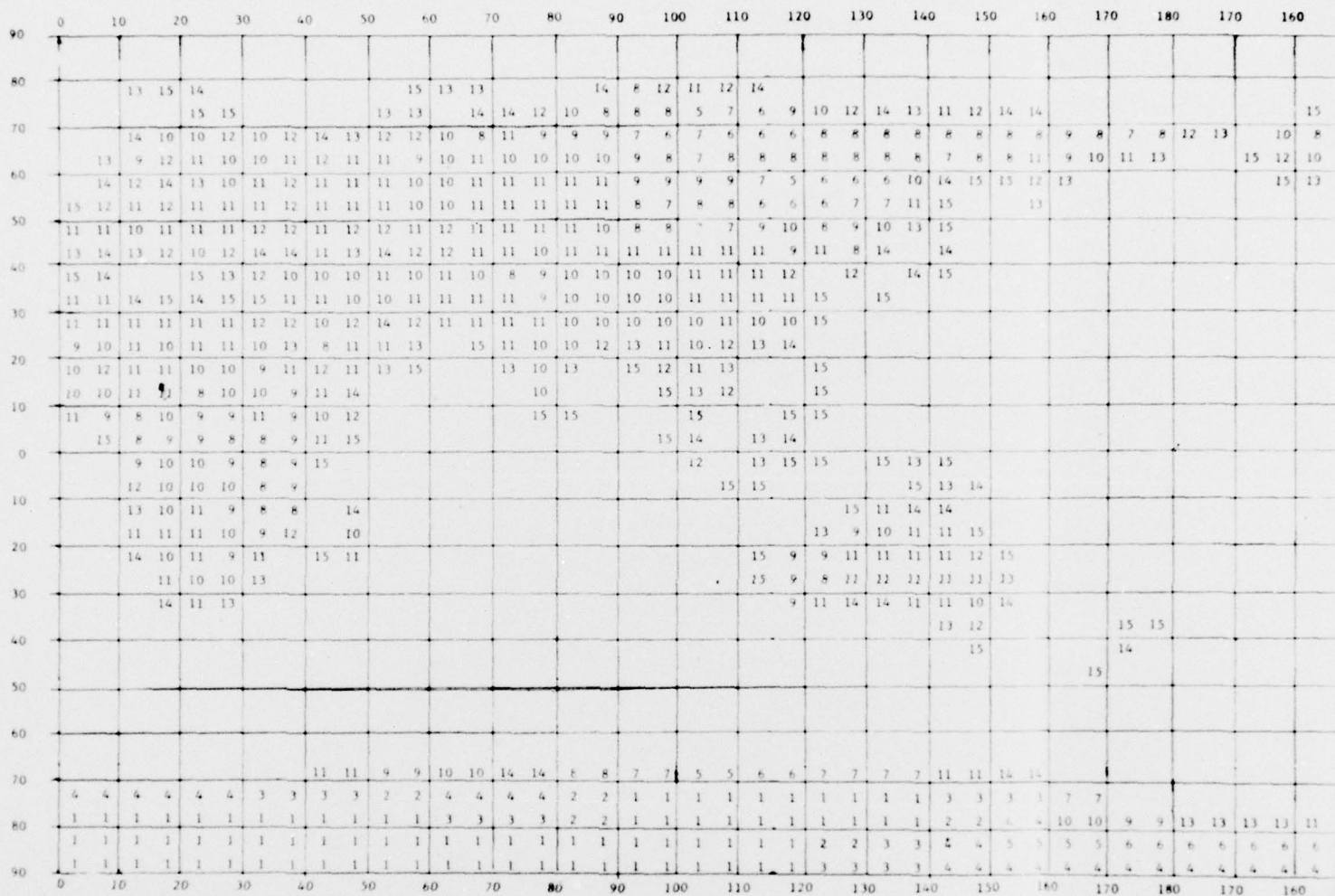
$$B4 = \frac{\pi}{2} - AA_6 = \frac{\pi}{2} - |\phi|$$

$$AA_5 = (B4)^3 = \left( \frac{\pi}{2} - |\phi| \right)^3$$

$$AA_2 = AA_5 * B1 = \left( \frac{\pi}{2} - |\phi| \right)^3 \sin \theta$$

$$AA_3 = AA_5 * B2 = \left( \frac{\pi}{2} - |\phi| \right)^3 \cos 2\theta$$

$$AA_4 = B4 * B2 - \left( \frac{\pi}{2} - |\phi| \right) \cos 2\theta$$



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FIGURE 2 CONDUCTIVITY MAP





c) The Conductivity Index, IC; p8/1 through p10/\$ 36+1:

This algorithm takes the position vector  $\vec{P}$  and searches the conductivity map to find the conductivity index IC of the region of the earth's surface corresponding to  $\vec{P}$ .

The conductivity map (Figure 2) has the following form:

For latitude north of  $55^\circ\text{S}$ , the earth is broken up into boxes each  $5^\circ$  by  $5^\circ$ .

For latitudes south of  $55^\circ\text{S}$ , the earth is broken up into boxes  $5^\circ$  in latitude and  $10^\circ$  in longitude.

There are 16 conductivity levels ranging from 16 (sea water) to 1 (permafrost).

The conductivity of each box is the average conductivity of the earth's surface within the box, weighted according to the areas of each conductivity. The Westinghouse Conductivity Map was used.

The three pages which describe the conductivity search are straightforward and do not require elaboration.

d) Diurnal Function, F; p11/3, 4:

From Table 4 under description for p4/\$55 the value for  $K(\text{JF}, \text{IS})$  is obtained. Then

$$F = FM_1 + K(\text{JF}, \text{IS}) FM_2$$

where JF is used as index to distinguish it from the diurnal function.

If this is first time through, then go to \$41; otherwise continue.

e) Correction Factors,  $C_{11}$ ,  $C_{21}$ ; p11/5:

$C_{11}$  is the correction factor for reconverted first mode of propagation.

$$C_{11}(\text{JF}) = C_{11}(\text{JF}) + K_{11}(\text{JF}) (F(\text{JF}) - F(\text{JF})_0)$$

$C_{21}$  is the correction factor for higher propagation modes.

$$C_{21}(\text{JF}) = C_{21}(\text{JF}) \alpha_0(\text{JF}) F(\text{JF}) + K_{21}(\text{JF}) (F(\text{JF}) - F(\text{JF})_0)$$

Here set  $F(\text{JF}) = F(\text{JF})_0$

where  $K_{21}$  and  $K_{11}$  are constants, defined for each frequency, and represent the excitation of 2nd mode and reexcitation of 1st mode,  $\alpha_0$  is the

relative nighttime attenuation of 2nd mode and is a function of frequency.

$\alpha_o(1) = 0.91$	$K_{11}(1) = 6.7$	$K_{21}(1) = 25.0$
$\alpha_o(2) = 0.925$	$K_{11}(2) = 6.7$	$K_{21}(2) = 25.0$
$\alpha_o(3) = 0.94$	$K_{11}(3) = 6.7$	$K_{21}(3) = 25.0$

e) Diurnal Function Average, GG; p11/\$ 42:

$$GG(JF) = GG(JF) + F(JF)$$

f) Integration; p12/1,2:

$$Q = \sum_{I=2}^6 CAY(JF, I) AA_I + CAY1(JF, IC)$$

$$A(JF) = Q C_4 C_5 + AAUR^*$$

$$Q = \sum_{I=2}^6 DCAY(JF, I) AA_I + DCAY1(JF, IC)$$

$$B(JF) = Q C_4 C_5 + BAUR^*$$

$$\Delta\theta_2 = C_1 C_4 C_5 RAT(JF) P_1^2$$

$$SUM \Delta\theta_2 = SUM \Delta\theta_2 + \Delta\theta_2$$

$$\Delta\theta_3 = (A(JF) + F(JF) B(JF)) RAT(JF)$$

$$SUM \Delta\theta_3 = SUM \Delta\theta_3 + \Delta\theta_3$$

where CAY, CAY1, DCAY, DCAY1 can be found in tables 6 and 7.

$$C_1 \text{ is the ellipsoidal correction constant} \\ = -0.336 \times 10^{-4}$$

$$C_4 \text{ is the chart conversion factor} \\ = 0.9974$$

$$C_5 \text{ is the nominal } 10.2 \text{ wavelengths/radian} \\ = 217.021.$$

\*Note that in the flow diagrams the terms AAUR, BAUR were erroneously excluded.

RAT(I) is the frequency conversion number

$$\text{RAT}(1) = 1.0$$

$$\text{RAT}(2) = 10/9$$

$$\text{RAT}(3) = 4/3$$

p12/3:

If more frequencies to process, then increment JF and return to p11/\$ 50 where more frequency-dependent terms will be generated.

If JF = 3, then continue.

TABLE 6 CAY and DCAY VALUES

<u>CAY (JF, I)</u>			
	10.2	11.3	13.6
1	323.0	291.0	242.0
2	Same	-0.4	Same
3	as	0.0	as
4	11.3	-0.65	11.3
5		0.0	
6		1.32	
<u>DCAY (JF, I)</u>			
1	207.0	185.0	155.0
2	2.8	2.36	1.82
3	-1.5	-1.44	-1.43
4	0.65	0.65	0.65
5	4.70	4.22	3.38
6	-1.32	-1.32	-1.32

Multiply all by  $10^{-6}$

TABLE 7 CAY1 and DCAY1 VALUES

CAY1 (JF, IC)

IC \ JF	10.2	11.3	13.6
1	-27.0	-32.0	-40.0
2	-20.0	-27.0	-35.0
3	9.0	- 8.0	-23.0
4	33.0	36.3	27.5
5	24.6	32.7	44.0
6	16.3	25.3	38.5
7	7.9	19.1	33.2
8	3.2	14.8	30.0
9	- 0.2	12.0	27.6
10	- 3.0	9.2	25.6
11	- 5.1	7.5	23.8
12	- 6.4	6.2	22.9
13	- 7.2	5.2	22.2
14	- 8.0	4.5	21.5
15	- 8.8	3.8	21.0
16	- 9.0	3.9	20.8

Multiply all by  $10^{-6}$

DCAY1 (JF, IC)

IC \ JF	10.2	11.3	13.6
1	0.0	30.0	60.0
2	3.8	28.2	55.0
3	8.3	21.2	38.5
4	5.5	5.5	12.0
5	22.3	19.4	15.2
6	26.3	23.3	19.2
7	30.2	27.0	23.3

TABLE 7 (continued)

JF IC	10.2	11.3	13.6
8	32.8	29.5	25.2
9	33.8	30.0	25.2
10	34.2	30.2	25.2
11	33.6	30.0	25.2
12	33.2	29.4	24.4
13	32.9	28.9	23.7
14	32.6	28.8	23.7
15	32.1	28.5	23.7
16	31.8	27.6	23.7

Multiply all by  $10^{-6}$

g) Integration Complete Test; p12/4 through p13/1:

The integration counter sums the number of  $d\theta$  increments used where  $d\theta = 0.01$  radian.

$$\vec{TEST} = \vec{P} - \vec{S}$$

$$\text{If } |\vec{TEST}| > (d\theta)^2$$

then Increment  $\vec{P}$

$$\vec{P} = (\vec{AX} \times \vec{P}) \cdot \sin(d\theta) + \vec{P} \cdot \cos(d\theta)$$

Return to Paragraph p4/\$ 55.

$$\text{If } |\vec{TEST}| \leq (d\theta)^2$$

Then continue.

3.1.2.3 Generation of Output Data

a) Averaging Constant, AVG; p13/\$ 60+1:

Corrects for incremental integration

$$AVG = \theta / n \Delta\theta$$

where n is number of increments used and  $\Delta\theta = 0.01$  radian.

b) Base Station Central Angle:

Call subroutine THETA1 to compute  $\theta_1$  (base)

c) Summation Average; p14/1:

$$\text{ASUM } \theta_2 = \text{AVG } (\text{SUM} \theta_2)$$

$$\text{ASUM } \theta_3 = \text{AVG } (\text{SUM} \theta_3)$$

(frequency dependence implied)

d) Propagation Correction;  $\theta_3$ :

$$\theta_3(\text{JF}) = \theta_3(\text{JF}) + \text{CAY}(\text{JF}, 1) + \frac{\Delta\theta_{\text{GG}}(\text{JF}) \text{DCAY}(\text{JF}, 1)}{\theta_1(\text{JF})}$$

e) Predicted Variance;  $\sigma_{\text{ppi}}^2$ ; p14/3:

Combine the effects of second mode and reconverted first to compute an estimate of the variance on the predicted phase.

$$\sigma_{\text{ppi}}^2 = (C_{21} + C_{11} + .04)^2$$

f) Spheroidal Correction;  $\theta_2$ , p14/4:

$$\theta_2(\text{JF}) = \text{ASUM} \theta_2$$

## 3.1.2.4 Tracking Filter Update

a) Predicted Tracking Filter Measurement,  $\theta_p$  (JF):

p14/6,7

$\theta_{\text{Ci}}$  (JF) for station i is obtained by subroutine THETAC. It is the predicted phase for station i.

p15/2

$\theta_{\text{Ck}}$  (JF) for base-station k is similarly calculated.



p15/3:

$$\theta_p(JF) = \theta_{ci}(JF) - \theta_{ck}(JF)$$

p15/\$ 45 + 1:

The integer lane count is adjusted in the tracking filter for station ik on frequency JF.

p15/\$ 45 + 2:

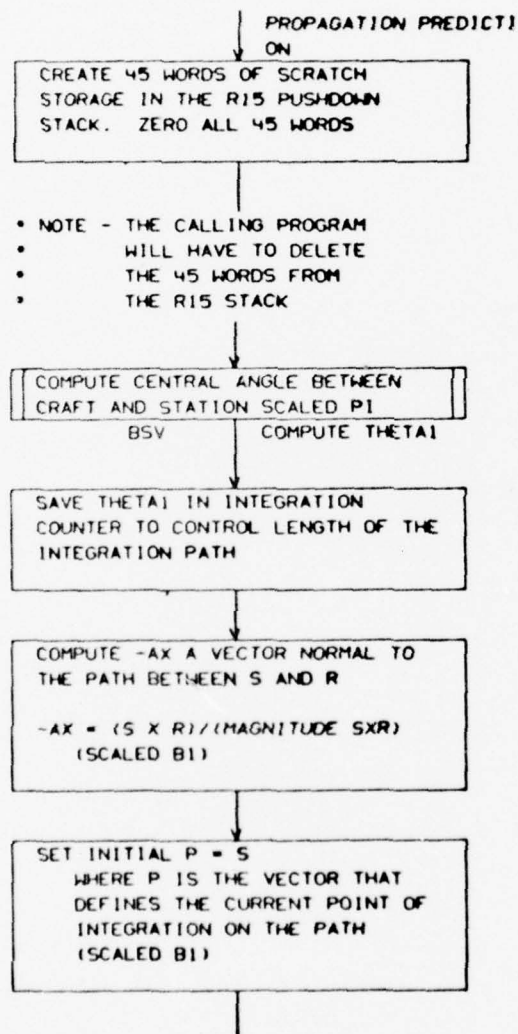
If more frequencies to process, increment JF and return to p13/\$ 61, otherwise exit.

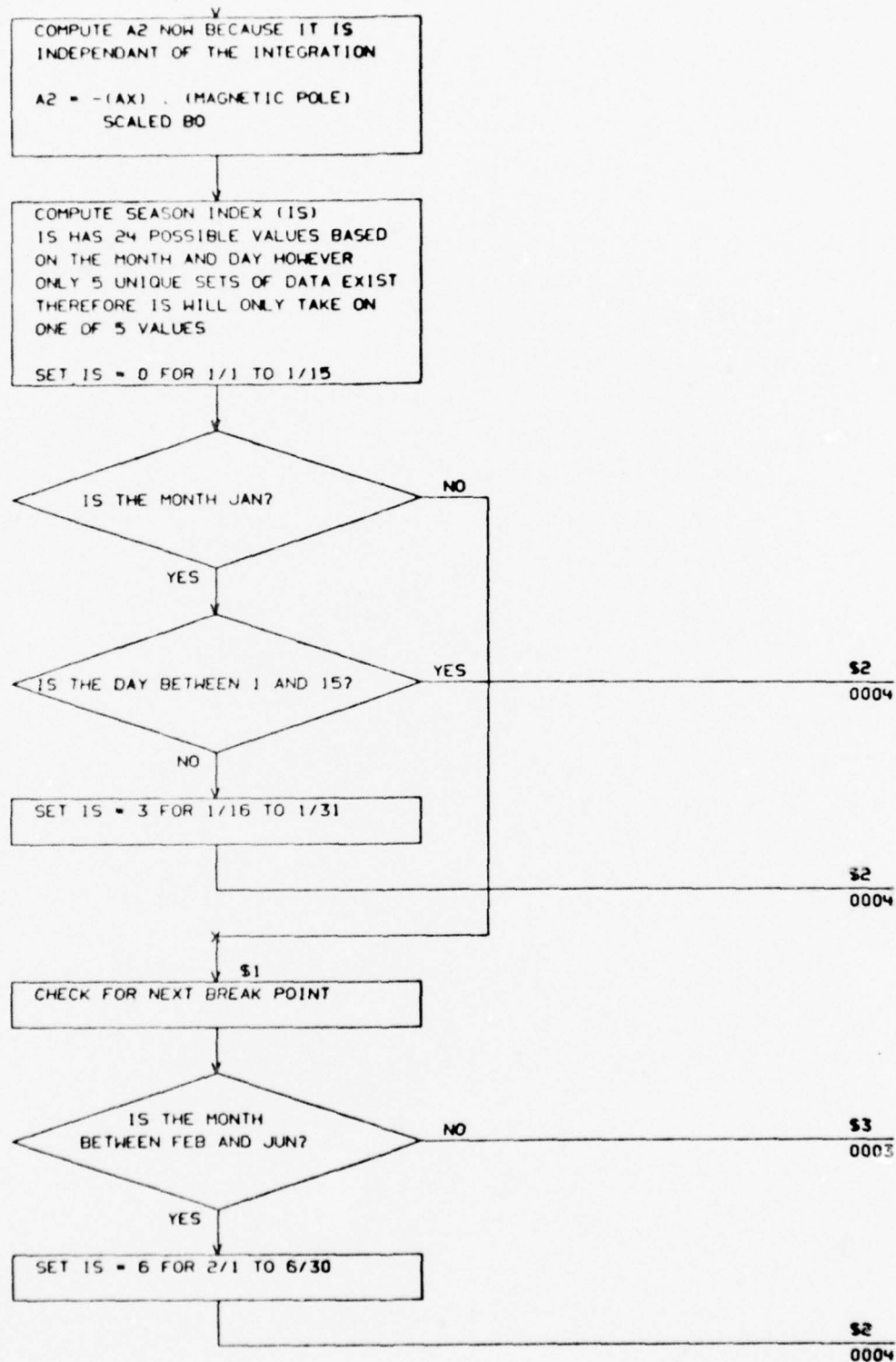
### 3.2 FLOW DIAGRAMS

The Propagation Prediction Subprogram flow diagrams are presented on the following pages.

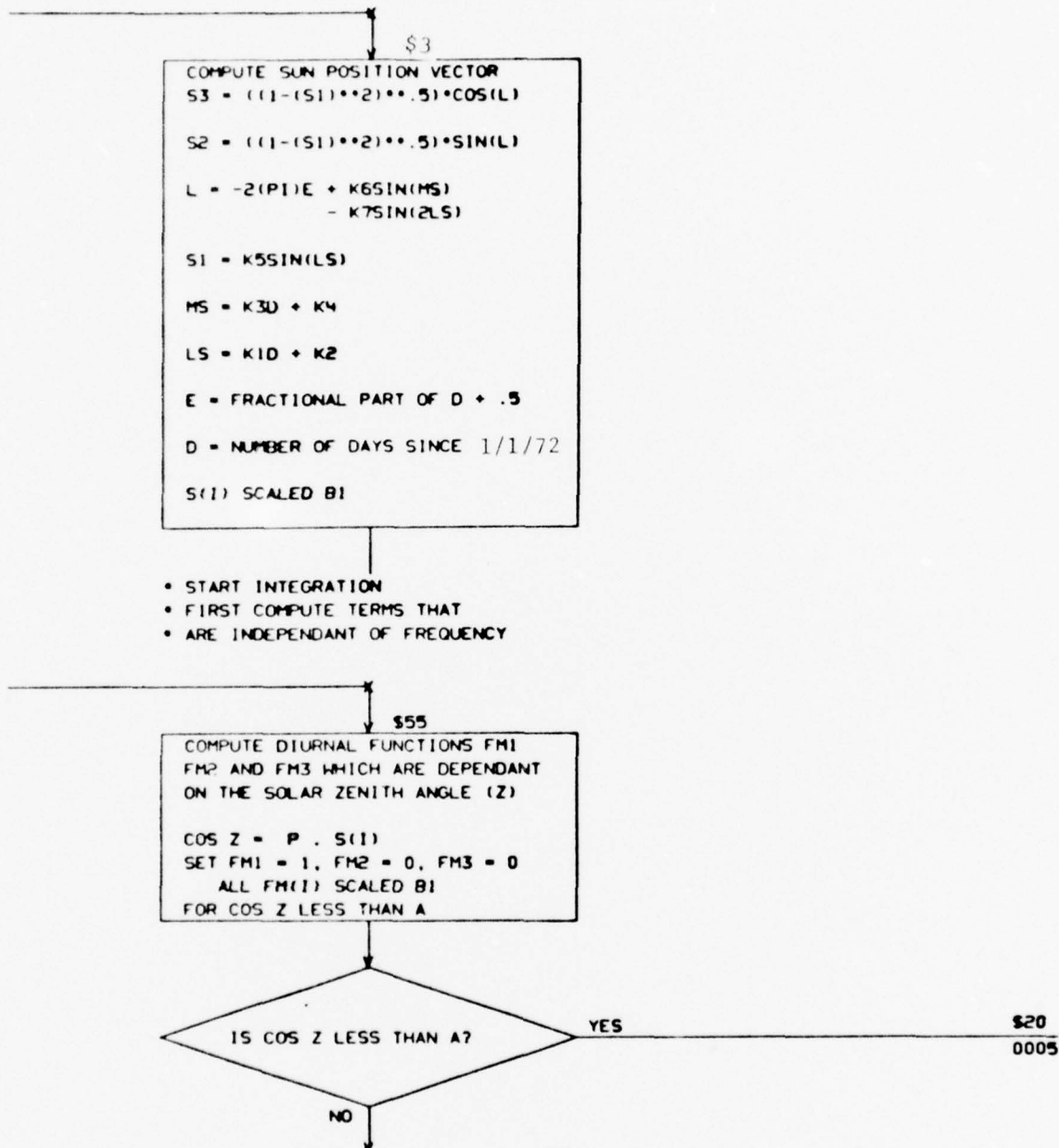


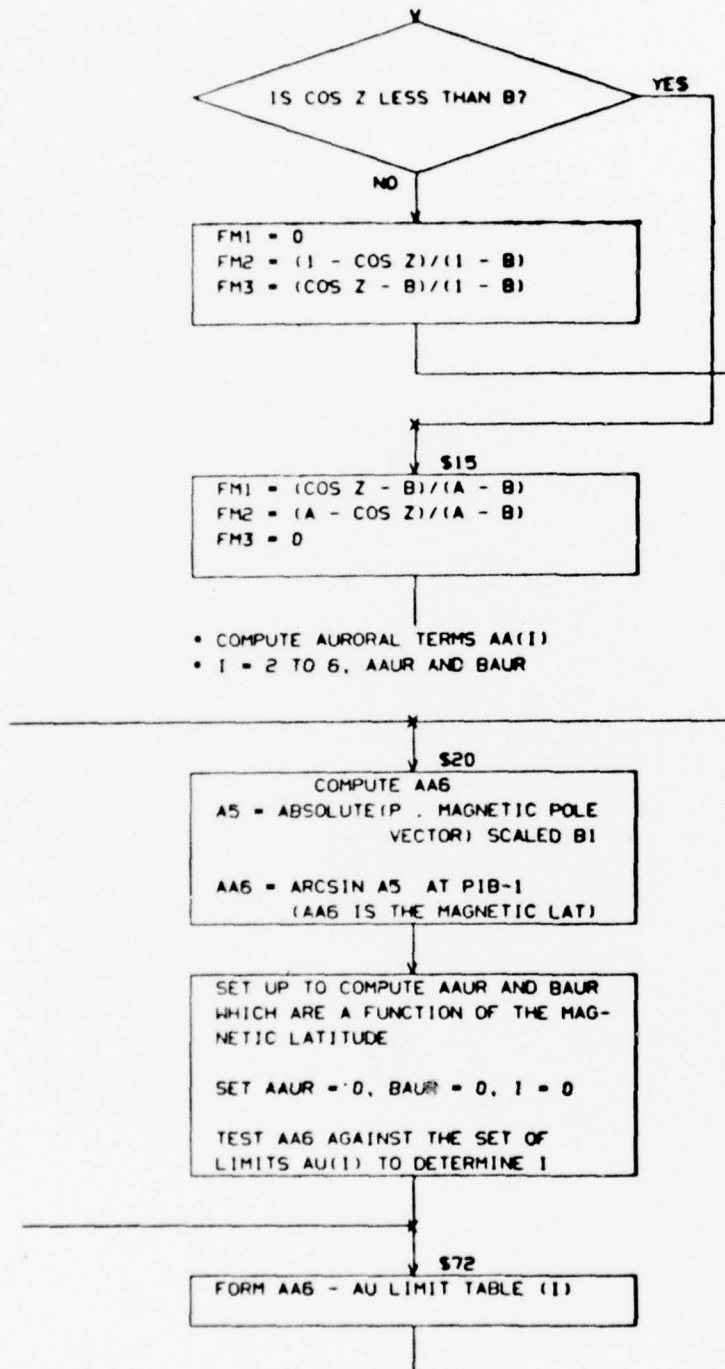
- 
- PROPAGATION PREDICTION
- 
- THIS PROGRAM WILL COMPUTE THE PREDICTED SPHEROIDAL ANE PROPAGATION
- CORRECTIONS TO THE NOMINAL PREDICTED PHASE MEASUREMENTS FROM A GIVEN
- STATION. IT ALSO COMPUTES AN ASSOCIATED VARIANCE. THE THREE PARA-
- METERS ARE COMPUTED FOR ALL 3 FREQUENCIES AND SAVED IN MEMORY FOR EACH
- STATION. THE TOTAL LANE COUNT FROM THE CORRECTED PREDICTED PHASE
- REPLACES ANY LANE COUNTS CONTAINED IN THE MEASURED PHASE IN THE
- TRACKING FILTER. THE STATION NUMBER IS THE ONLY ARGUMENT.
- 



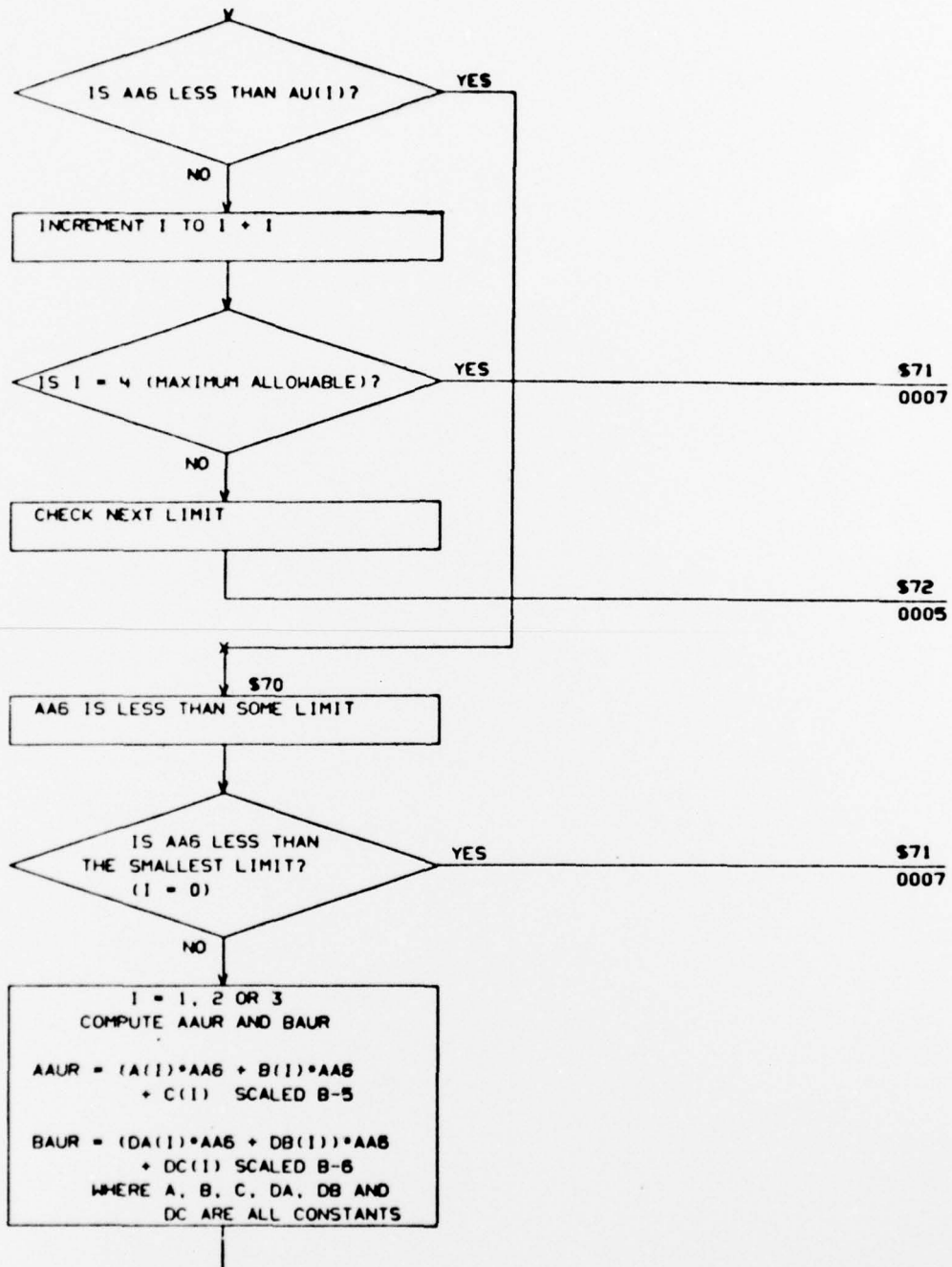


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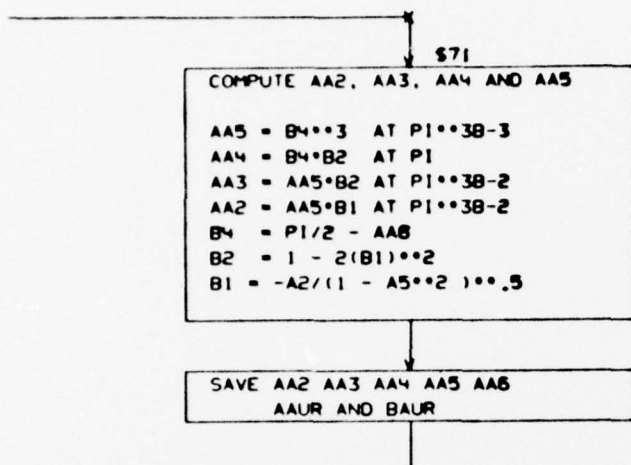




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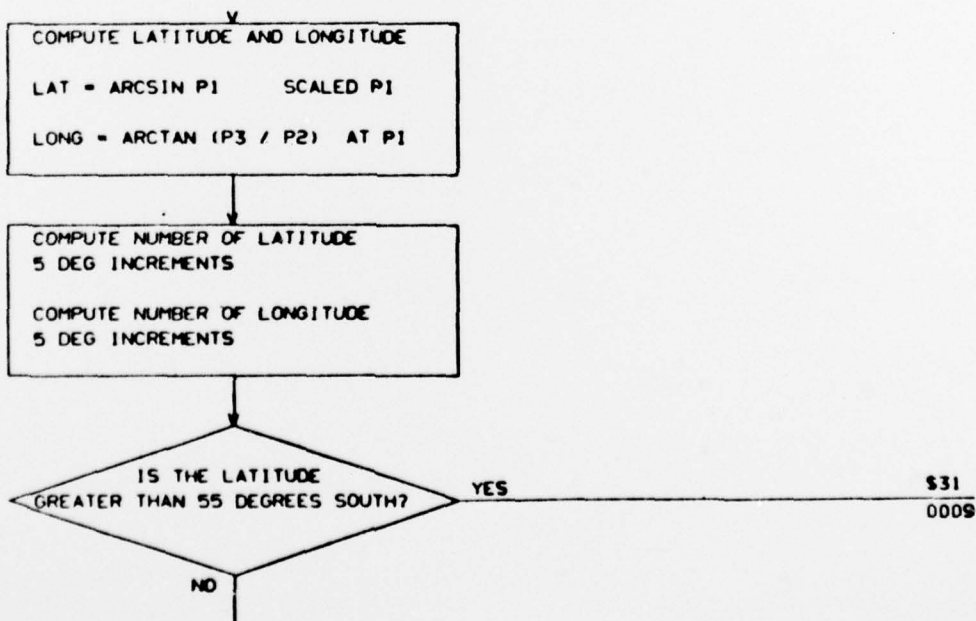




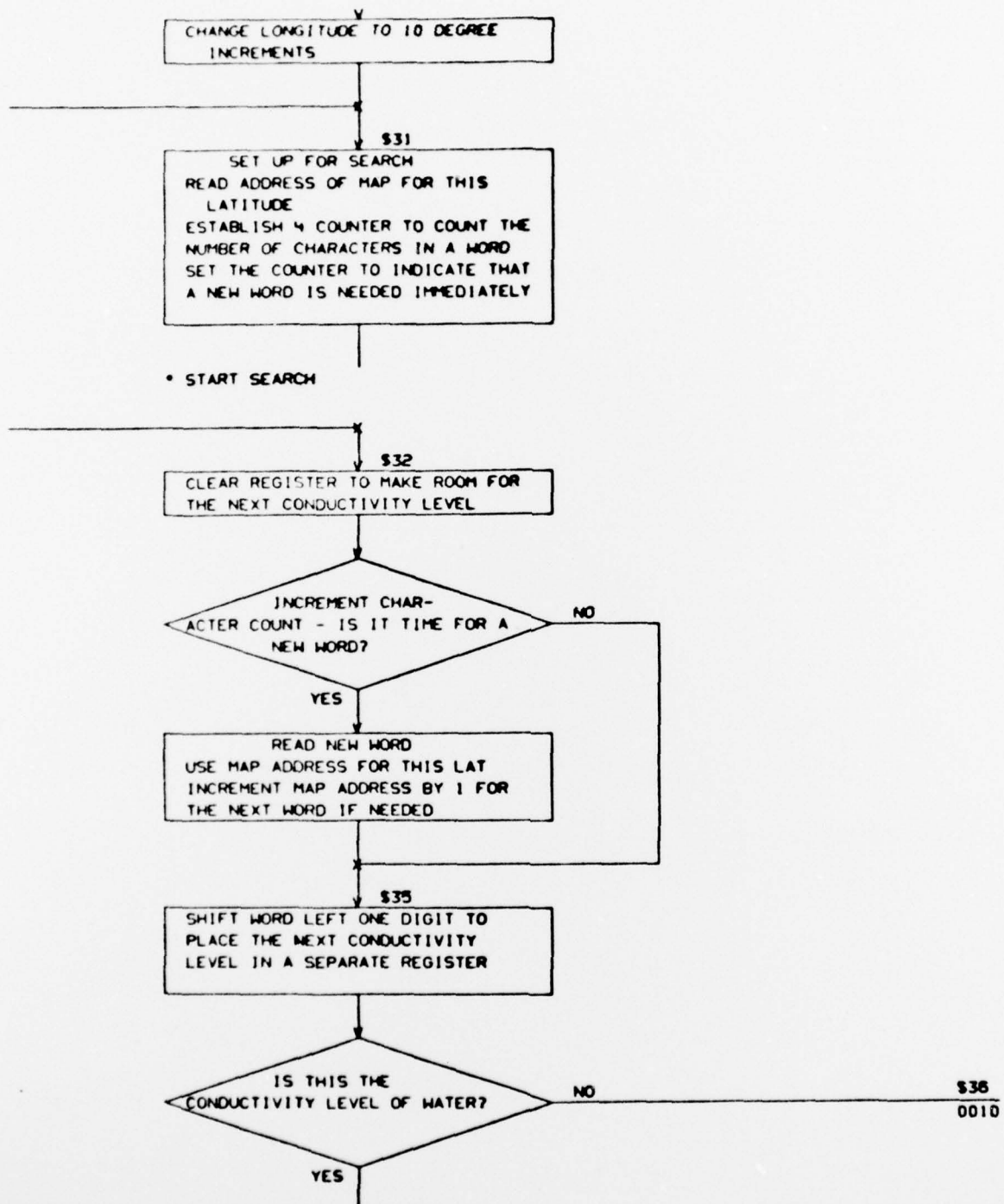


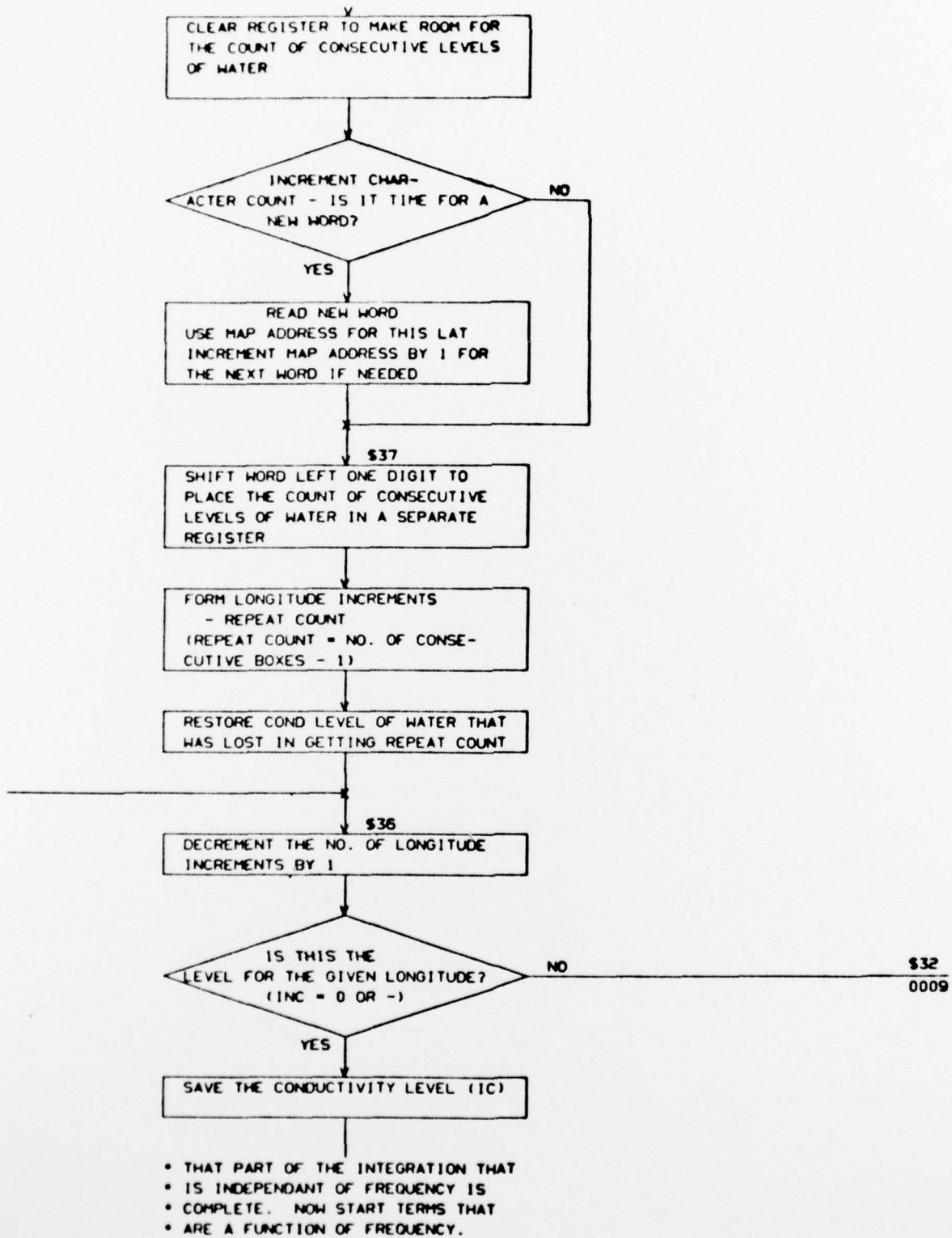
## DETERMINE CONDUCTIVITY LEVEL

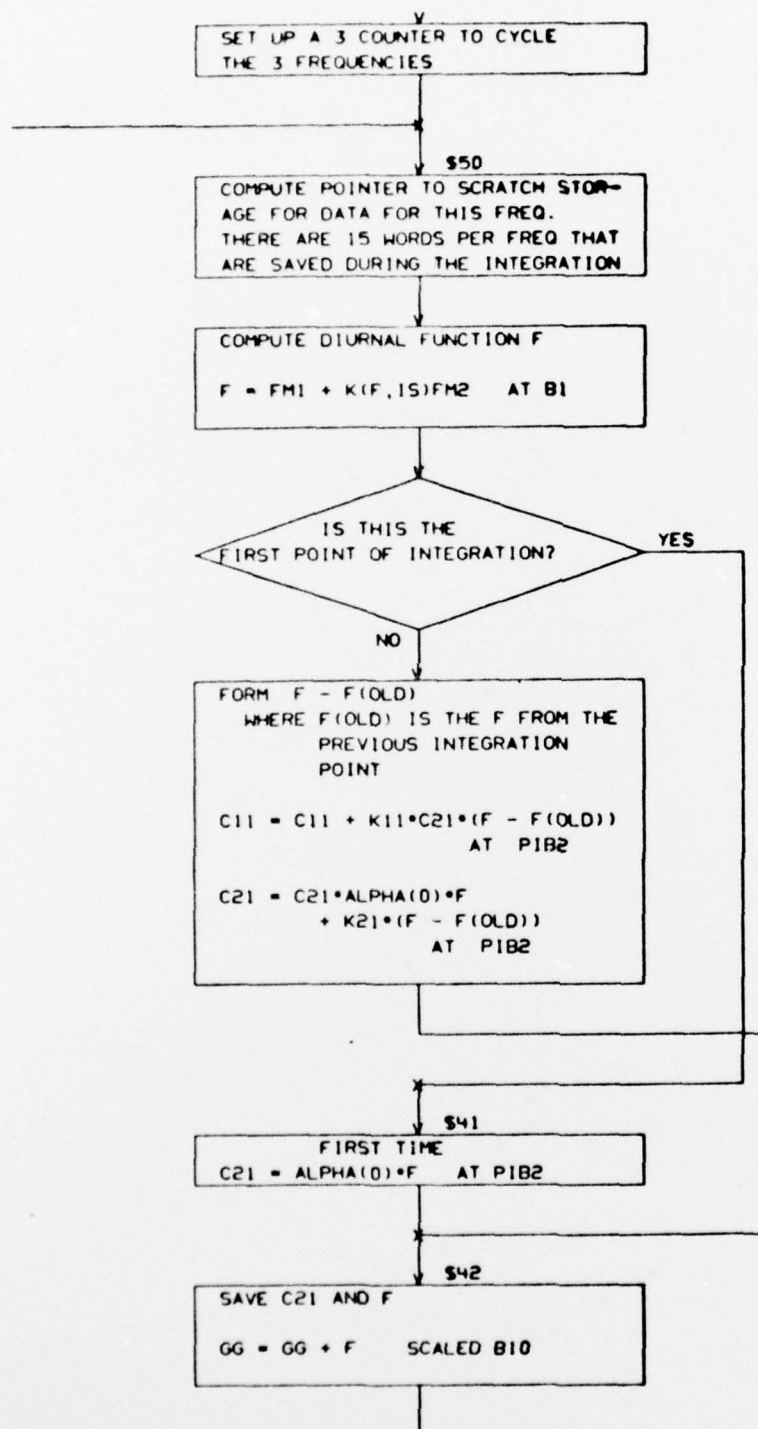
- 
- THE FOLLOWING SECTION OF THE PROPAGATION PREDICTION PROGRAM USES THE CONDUCTIVITY MAP TO DETERMINE THE CONDUCTIVITY LEVEL AT THE PRESENT POINT ON THE PATH OF INTEGRATION DEFINED BY THE VECTOR P. FOR PROGRAMMING EFFICIENCY THE EARTH HAS BEEN DIVIDED INTO BOXES EVERY FIVE DEGREES OF LATITUDE AND LONGITUDE EXCEPT THAT BELOW SOUTH 55 LATITUDE THE LONGITUDE SIDES ARE 10 DEGREES IN LENGTH. THE MAP HAS BEEN DIVIDED INTO 36 PARTS (1 FOR EACH INCREMENT OF LATITUDE) AND A TABLE OF ADDRESSES POINTS TO THE PART OF THE MAP THAT IS TO BE USED FOR A GIVEN LATITUDE. THE PROPER ENTRY IS DETERMINED BY COMPUTING THE NUMBER OF 5 DEG LATITUDE INCREMENTS ABOVE THE SOUTH POLE. THE FIRST ENTRY IS FOR 90S TO 85S AND THE LAST ENTRY IS FOR 85N TO 90N. FOR A GIVEN LATITUDE THE 4 BIT CONDUCTIVITY LEVELS FOR THE LONGITUDE INCREMENTS ARE STORED IN CONSECUTIVE HEXADECIMAL CHARACTERS STARTING AT 20 DEG EAST LONGITUDE AND CONTINUING ALL THE WAY AROUND THE EARTH FOR INCREASING EAST LONGITUDE. THE CORRECT CONDUCTIVITY LEVEL IS THEN OBTAINED BY COMPUTING THE NUMBER OF LONGITUDE INCREMENTS AND COUNTING THROUGH THE TABLE UNTIL THE CORRECT ITEM IS REACHED.
- EACH 16 BIT COMPUTER WORD CONTAINS THE CONDUCTIVITY LEVEL FOR FOUR INCREMENTS OF LONGITUDE. THE MOST SIGNIFICANT 4 BITS OF THE FIRST WORD OF THE MAP FOR A GIVEN LATITUDE CONTAIN THE LEVEL BETWEEN 20 AND 25 DEG EAST LONG. THE LEAST SIGNIFICANT 4 BITS ARE FOR LONG E35 TO E40. THE MAP THEN CONTINUES IN THE NEXT HIGHER MEMORY LOCATION FOR THE NEXT LONGITUDE INCREMENT. THE CONDUCTIVITY LEVEL IS A NUMBER BETWEEN 0 AND 15 THAT IS USED TO INDEX A TABLE.
- BECAUSE MOST OF THE EARTH IS WATER AND THEREFORE HAS THE SAME CONDUCTIVITY LEVEL A COMPACTING TECHNIQUE IS USED THAT REDUCES THE SIZE OF THE TABLE BY APPROXIMATELY HALF. WHENEVER THE LEVEL FOR WATER (15) IS ENCOUNTERED FOR A LONGITUDE THE NEXT HEXADECIMAL CHARACTER IS A COUNT OF THE NUMBER OF CONSECUTIVE BOXES OF WATER FOR THAT LONGITUDE UP TO A MAXIMUM OF 15.
- 

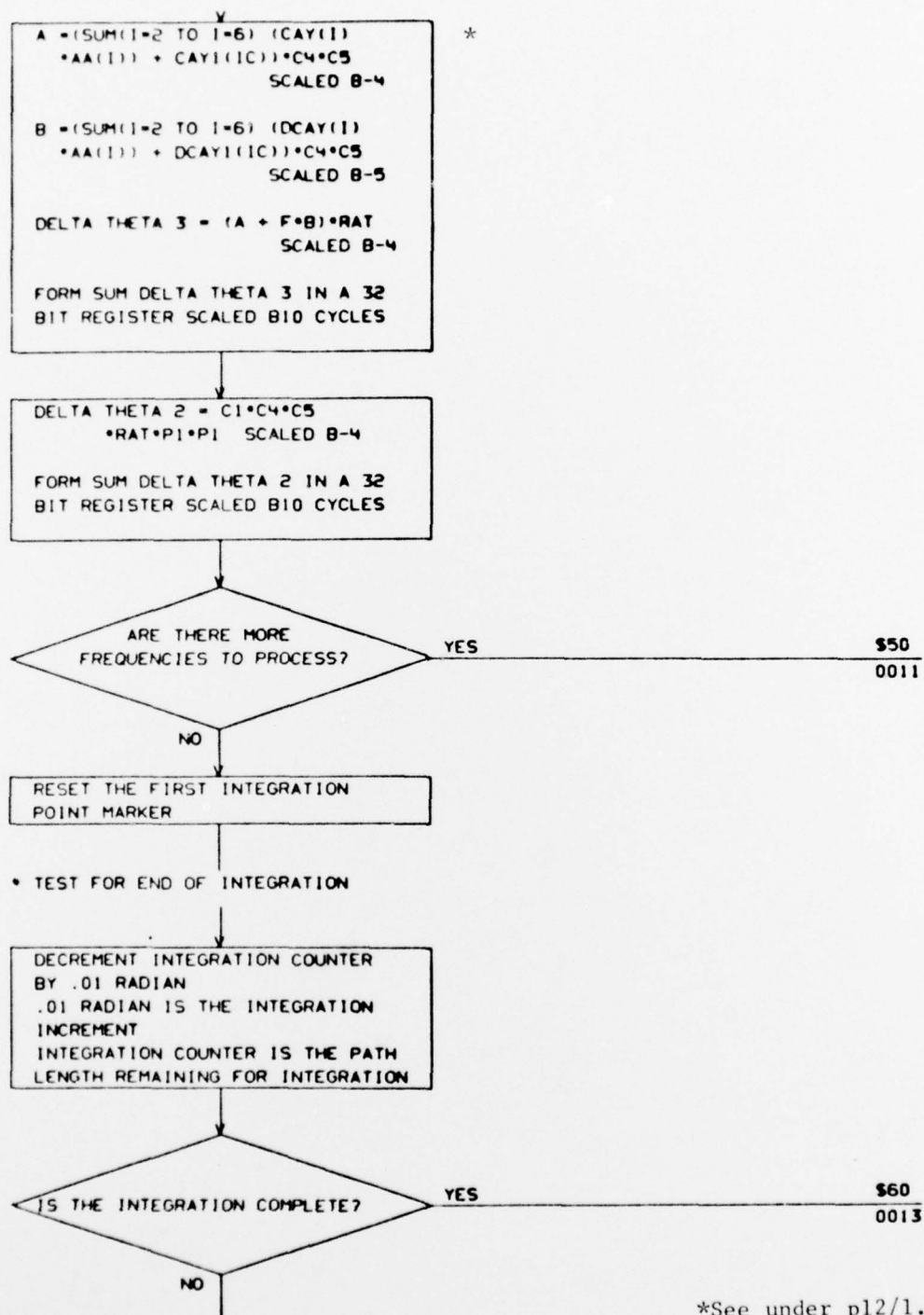








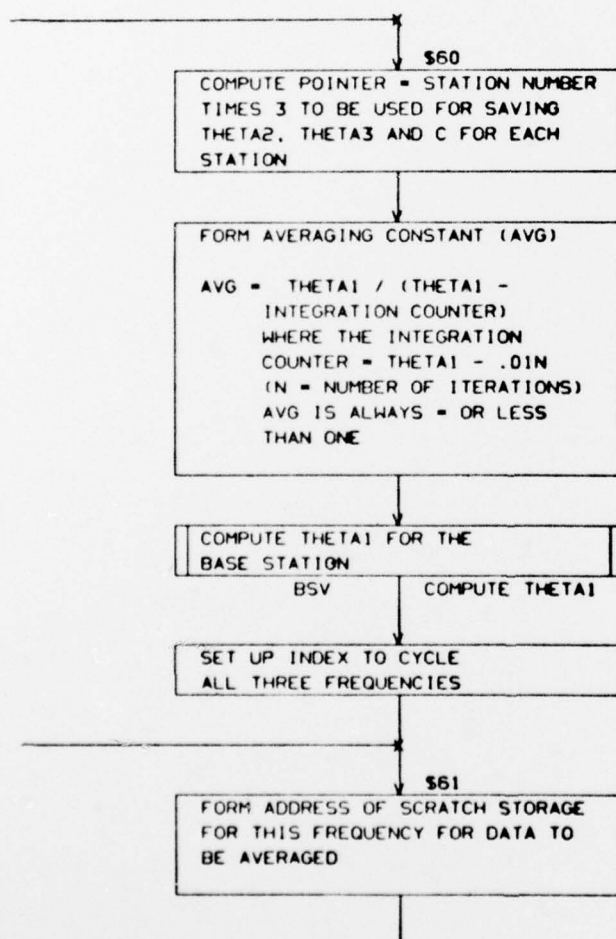


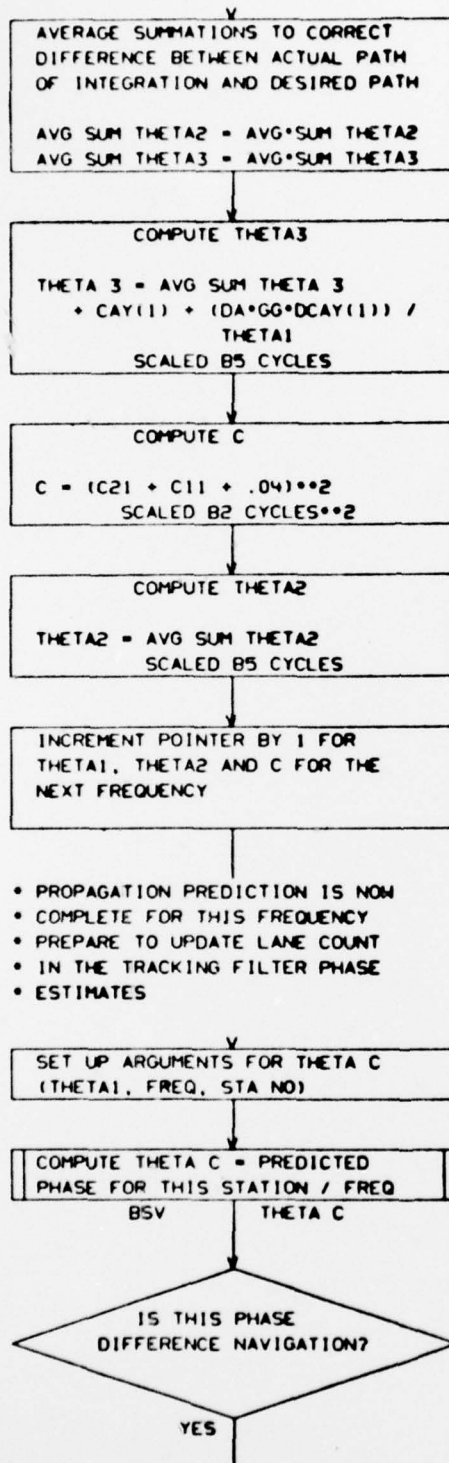


ROTATE P THROUGH THE INTEGRATION  
INCREMENT  $DA = .01$  RADIAN  
 $P(NEW) = PCOSDA + (AX \times P)SINDA$

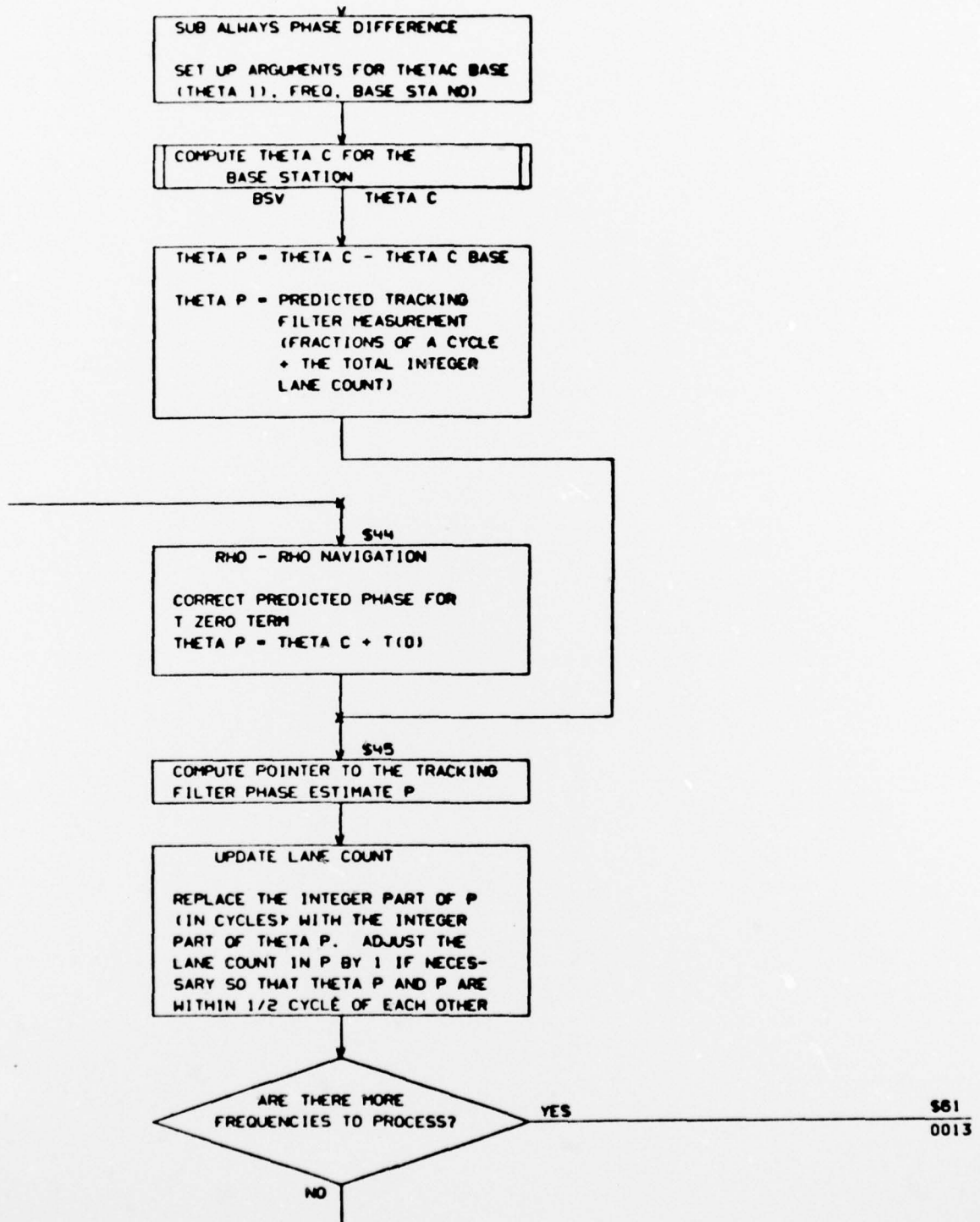
\$55  
0004

- INTEGRATION COMPLETE
- 
- NOTE - THE INTEGRATION WAS
- ACTUALLY PERFORMED
- OVER A RANGE OF N TIMES
- THE INTEGRATION INCRE-
- MENT OF .01 RADIAN.
- THETA1 IS LESS THAN
- .01N WHICH IS LESS
- THAN THETA1 + .01
- 









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<sup>Y</sup>  
EXIT

THE ARGUMENT IS UNDISTURBED  
45 WORDS HAVE BEEN ADDED TO THE  
R15 PUSH DOWNSTACK

BOX

### 3.3 COMPUTER SUBPROGRAM ENVIRONMENT

#### 3.3.1 Propagation Prediction Tables

- a) Magnetic Pole: This table contains the three-element vector that defines the position of the North Magnetic Pole. It is defined in detail in the listing. The official name of this table is NORTH MAGNETIC POLE VECTOR.
- b) Auroral Compensation Limits: This table is used to test the Magnetic Latitude for selection of the appropriate auroral constants. The first entry is the lowest limit (AU(1)), the second entry is AU(2)-AU(1), the third entry is AU(3)-AU(2) and the last entry is AU(4)-AU(3). See the listing for more detail. The official name of this table is AUR LIMITS.
- c) Conductivity Table: This table defines the conductivity level for any point on the earth. It is defined in detail in the flow charts and in the listing. The official name of this table is COND TABLE.
- d) Diurnal Constants: This table contains the diurnal constants for the calculation of the diurnal function F. For convenience, the five different entries in the original table for the 24 values of the season index have been renumbered 0 to 4. This table is defined in detail in the listing. The official name of this table is DIURNAL CONSTANT TABLE.
- e) Second Mode Excitation Factor: This table is used in the computation of PROP C. It is defined in detail in the listing. The official name of this table is K21.
- f) Second Mode Relative Night Attenuation Factor: This table is used in the computation of PROP C. It is defined in detail in the listing. The official name of this table is ALPHA 0.
- g) Model Constants: This table contains five entries for CAY(2) to CAY(6) used in the computation of A. Each entry has been modified by C4 and C5. It is defined in detail in the listing. The official name of this table is CAY TABLE.
- h) Model Constants: This table contains five entries for each frequency for DCAY(2) to DCAY(6). Each entry has been modified by C4 and C5. It is defined in detail in the listing. The official name of this table is DCAY TABLE.
- i) Conductivity Constants: This table contains 16 entries for each frequency for CAY1(1) to CAY1(16). Each entry has been modified by C4 and C5. It is defined in detail in the listing. The official name of this table is CAY1 TABLE.

- j) Conductivity Constants: This table contains 16 entries for each frequency for DCAY1(1) to DCAY1(16). Each entry has been modified by C4 and C5. It is defined in detail in the listing. The official name of this table is DCAY1 TABLE.
- k) Frequency Conversion Factor: This table contains the factors that convert 10.2 data into 13.6 or 11.3. It is defined in detail in the listing. This official name of this table is RAT.
- l) Ellipsoidal Correction: This table contains C1 modified by C4, C5 and the frequency conversion factors. It is defined in detail in the listing. The official name of this table is C1 TABLE.
- m) Model Constants: This table contains CAY(1) modified by C4, C5 and the frequency conversion factor. It is defined in detail in the listing. The official name of this table is CAY ONE.
- n) Model Constants: This table contains DCAY(1) modified by C4, C5 and the frequency conversion factor. It is defined in detail in the listing. The official name of the table is DCAY ONE.
- o) Auroral Constants: This table contains the three sets of auroral constants modified by C4 and C5. It is defined in detail in the listing. The official name of this table is AUR DATA.
- p) Station Locations: This table contains the locations of all existing OMEGA transmitting stations. Each location is specified in a three-element geocentric position vector. The first entry is for station A. The table is defined in detail in the listing. The official name of this table is STATION VECTOR TABLE.

### 3.3.2 Propagation Prediction Temporary Storage

All temporary storage used by the Propagation Prediction Program is in the R15 pushdown stack except for seven words associated with the Auroral corrections called AUR SAVE which are placed in the Kalman program storage for new state vectors during measurement update.

3.3.3 Required System Library Subroutines

<u>SUBROUTINE</u>	<u>FLOW DIAGRAM REFERENCE</u>	<u>SUBPROGRAM DESIGN DOCUMENT (by Volume Number)</u>
ASIN	p5/\$ 20	All Subroutines found in Volume XII
CROSS	p1/3	
	p1/5	
DOT	p1/3	
SIN-Cos	p4/1	
SQRT	p1/5 p7/\$ 71	
	p4/1	
THETA1	p1/3	
THETAC	p14/6	
	p15/2	